A NEURAL NETWORK ELECTROMAGNETIC APPROACH FOR GPR PAVEMENT DIAGNOSTIC: A PRELIMINARY STUDY

Salvatore Caorsi and Mattia Stasolla

Department of Electronics
University of Pavia
via Ferrata 1, 27100 Pavia, Italy

1. INTRODUCTION

Pavement profiling is a challenging branch of GPR application fields that in the last decade has assumed more and more interest due to the non-destructive nature of investigations and the possibility of real-time surveys made possible by technology improvements [1]. It consists in the estimation of the subsurface properties (i.e. thickness and permittivity) of the pavement [2], whose vertical cross section is generally made up of 4 layers: *surface/wearing course*, *binder course*, *base* and *subgrade*. This suggests that the GPR signal's propagation can be studied by modeling an e.m. source irradiating a multi-layered medium composed of N parallel homogenous layers. To this end, some techniques based on analytical inversion of the e.m. signal have been proposed, especially for monostatic GPRs [3],[4], but (semi-)automated techniques for data analysis are still needed.

2. METHODOLOGY

The authors have recently shown that it is possible to determine the dielectric properties of the ground layer by extracting from the received e.m. signal a physical parameter which can be related to the reflection coefficient and therefore to the permittivity [5]. The reconstruction of the actual ϵ_r value is obtained by feeding an artificial neural network (ANN), since it does not perform an analytical inversion process and is able to cope with possible fluctuations due to noise and different environmental conditions.

On this basis, the proposed work is a preliminary study on the possibility of applying a recursive procedure that iteratively analyzes the pavement layers to provide their permittivity and thickness. A basic requirement regards the bistatic GPR design: transmitter (TX) and receiver (RX) relative positions and/or pulse length must be implemented so that the direct signal coupling them is separated from the first echo generated at the air/ground interface. The rationale behind is that the procedure needs an initial calibration step where the first echo received from a layer with known permittivity (e.g. if the antenna is placed over a metal plate) is isolated and taken as a reference signal e_o. Assumed that all the media are non-dispersive, we can consider that the signals generated at discontinuities reach the RX as scaled replicas of the reference echo. Therefore, starting from the first received echo ($k=1$) it is possible to detect the presence of any subsequent echoes ($k=2,3,\ldots,n$) by searching throughout the overall waveform sensed at RX fluctuations within the reference energy E_0. Once the $k+1$ echo is detected, the scaling factor (R_k) and the arrival time (t_{k+1}) are derived, and the procedure repeated iteratively for each k until the end of the radargram trace.

$$R_k = \frac{E_k}{E_0} = \frac{\int_0^t e_k^2(t')\,\mathrm{d}t'}{\int_0^t e_0^2(t')\,\mathrm{d}t'} = \frac{\int_0^t \alpha_k^2 e_0(t')\,\mathrm{d}t'}{\int_0^t e_0(t')\,\mathrm{d}t'} = \alpha_k^2 \quad (1)$$

Once the parameter R_k has been evaluated it is possible, together with t_{k+1}, to reconstruct layer's permittivity and thickness by means of ANN techniques.

3. RESULTS

In this preliminary study, we aim at assessing the capabilities of the recursive ANN approach in case of a generic multi-layered geometry, composed, for the sake of simplicity, of non-dispersive layers. In particular, it will be shown that the parameters R_k and t_{k+1} can be extracted from the e.m. signal irrespectively of the dielectric and geometric characteristics of the deeper layers.

This allows to simplify the problem and to deal with a scenario where only a subsurface layer is considered. Therefore, the basic module of the recursive procedure needs first to compute the scaling factor for the first echo (R_1) and the arrival time of the second (t_2), and then to feed a suitable ANN, whose architecture is shown in Fig. 1. The approach will be described from the theoretical point of view and tested, stressing its potentialities and drawbacks, over the most common sets of permittivities and thicknesses employed in pavement construction.

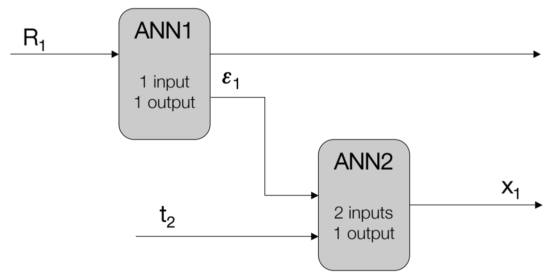

Fig. 1. ANN architecture.

4. REFERENCES

[1] Loizos, A. Plati, C., "Accuracy of Ground Penetrating Radar Horn-Antenna Technique for Sensing Pavement Subsurface", Sensors Journal, IEEE, vol. 7, no. 5, May 2007.

[2] Wu, R.; Li, X.; Li, J, "Continuous pavement profiling with ground-penetrating radar," Radar, Sonar and Navigation, IEE Proceedings, vol. 149, no. 4, Aug 2002, pp. 183–193.

[3] Gentili G.G., Spagnolini, U., "Electromagnetic Inversion in Monostatic Ground Penetrating Radar: TEM Horn Calibration and Application", IEEE Trans. on Geoscience and Remote Sensing, vol. 38, no. 4, Jul 2000.

[4] Lambot, S. Slob, E.C. van den Bosch, I. Stockbroeckx, B. Vanclooster, M., "Modeling of ground-penetrating Radar for accurate characterization of subsurface electric properties", Geoscience and Remote Sensing, IEEE Transactions on, vol. 42, no. 11, pp. 2555–2568, Nov 2004.

[5] Caorsi, S. and Stasolla, M., "ANN-based sub-surface monitoring technique exploiting electromagnetic features extracted by GPR signals", Adv. Geosci., vol. 19, pp. 3-9, 2008.